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INVESTIGATIONS REGARDING THE PHLOEM AND FOOD-CONDUCTION IN PLANTS, . . . . . *Frank U. G. Agrelius.*

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## INVESTIGATIONS REGARDING THE PHLOËM AND FOOD-CONDUCTION IN PLANTS.

BY FRANK U. G. AGRELIUS.

Plates XXXVI-XXXVII.

THIS work is an inquiry into the special devices for the lateral transfer of food materials in the phloëm of vascular plants; to see whether sieve tubes are always present in the higher plants; and to make some comparative studies of the phloëm in stems, petioles and fruitstalks.

At first material in the winter condition was tried but did not prove satisfactory, on account of the difficulty of identifying the sieve tubes in their winter condition. Material was again collected, this time including stems, petioles and fruitstalks, from the spring and summer growth, where the sieve tubes were functioning. Vines were selected at first, from the supposition that the conducting elements would be better developed and therefore plainer. This material was preserved in two-per-cent formaldehyde. As shrinkage of the protoplasm would really assist in making the cell walls more distinct, but little attempt was made to prevent it in the various processes of preparation.

The celloidin method of imbedding was tried at first but it did not serve the purpose well. It was rather essential in the hard material first collected, but the paraffin method worked better in most cases. By the celloidin method slides having the required large number of sections upon them were difficult to make. If the celloidin were left in the sections it stained too much like the cellulose walls. If dissolved out the cuttings were liable to cupping or to injury in the region of the cambium. These facts led to the choice of the paraffin method,

which was used where possible and which proved quite satisfactory in the majority of cases. The oldest material possible was commonly used.

Stains adapted to the work in hand were not found at first. Iodine green and erythrosin were tried, but this method left the phloëm red or pink—a poor color for the purpose. Finally fuchsin for the lignified walls and methyl blue for the cellulose ones were found to be quite satisfactory. The latter gave a fairly dark wall and slime body—the one better for making the drawings, the other rendering the identification of the sieve tubes less difficult.

The sections of such varied kind as to subject and age of material stained quite differently under the same treatment, so that each one usually required some variation. The slides were left in the fuchsin from two hours to several days. The excess stain was removed with acid-alcohol, and the slides were then placed in methyl blue for from twenty seconds to three or four minutes.

As a rule, cross, radial and tangential sections, with many mounts on each slide, were prepared for each subject—in all, more than 300 slides. These included specimens from young and from somewhat older material. The tangential sections proved the best for demonstrating sieve tubes. The cross sections were best for the measurements of cell walls and cell cavities, and to show the locality of the various tissues, etc. All were used to determine, if possible, the presence of pits, or of any other facts bearing on the problem.

## PLANTS EXAMINED.

The following is a list of the plants examined, arranged according to the classification of Gray's revised manual:

Pinaceæ:
- Pinus laricio Port.

Alismaceæ:
- Sagittaria latifolia Willd.

Gramineæ:
- Zea Mays Linn.

Cyperaceæ:
- Scirpus validus (Vahl.) L.

Bromeliaceæ:
- Tillandsia usneoides L.

Liliaceæ:
- Yucca glauca Nutt.
- Asparagus officinalis L.
- Smilax rotundifolia L.

Salicaceæ:
- Salix alba, var. vitellina (L.) Koch.
- Populus alba L.
- Populus deltoides Marsh.

Juglandaceæ:
- Juglans nigra L.

Urticaceæ:
- Ulmus fulva Mx.
- Ulmus americana L.
- Celtis occidentalis L.
- Cannabis sativa L.
- Humulus Lupulus L.
- Morus rubra L.

Aristolochiaceæ:
Aristolochia macrophylla Lam.
Aristolochia tomentosa Sims.
Ranunculaceæ:
Clematis Pitcheri T. & G.
Anonaceæ:
Asimina triloba Dunal.
Menispermaceæ:
Menispermum canadense L.
Saxifragaceæ:
Deutzia Fortunei Hors.
Rosaceæ:
Spiræa japonica L. (?)
Pyrus Malus Linn.
Fragaria virginiana Deuchesne.
Rubus occidentalis L.
Rubus cuneifolius Pursh.
Rosa pratincola Greene.
Prunus americana Marshall.
Leguminosæ:
Gymnocladus dioica (L.) Koch.
Gleditsia triacanthos L.
Melilotus alba Desr.
Amorpha fruticosa L.
Desmodium canescens (L.) DC.
Rutaceæ:
Zanthoxylum americanum Mill.
Simarubaceæ:
Ailanthus glandulosa Desf.
Anacardiaceæ:
Rhus glabra L.
Rhus toxicodendron L.
Rhus cotinus L.
Celastraceæ:
Celastrus scandens L.
Aceraceæ:
Acer saccharinum L.
Acer Negundo L.
Rhamnaceæ:
Rhamnus lanceolata Pursh.
Vitaceæ:
Psedera quinquefolia (L.) Greene.
Vitis æstivalis Mx.
Tiliaceæ:
Tilia americana L.
Malvaceæ:
Abutilon Theophrasti Medic.
Cactaceæ:
Opuntia Rafinesquii Engelm.
Haloragidaceæ:
Myriophyllum heterophyllum Mx.
Cornaceæ:
Cornus asperifolia Mx.
Oleaceæ:
Fraxinus viridis Mx. (?).
Syringa vulgaris L.
Asclepiadaceæ:
Asclepiodora viridis (Walt.) Gray.
Asclepias syriaca L.
Convolvulaceæ:
Cuscuta glomerata Choisy.
Labiatæ:
Monarda fistulosa L.
Solanaceæ:
Lycium halimifolium Mill.
Scrophulariaceæ:
Verbascum Thapsus L.
Bignoniaceæ:
Tecoma radicans (L.) Juss.
Catalpa speciosa Warder.
Plantaginaceæ:
Plantago virginica L.
Caprifoliaceæ:
Symphoricarpos orbiculatus Moench.
Triosteum perfoliatum L.
Sambucus canadensis L.
Cucurbitaceæ:
Cucurbita pepo L.
Compositæ:
Brauneria pallida (Nutt.) Britton.
Gaillardia grandiflora ?
Arctium Lappa L.
Cirsium discolor (Muhl.) Spring.
Lepachys pinnata (Vent.)

These range from the Pinaceæ to the Compositæ. They include one parasite, one epiphyte, three hydrophytes and two xerophytes. The list embraces twenty-three herbaceous plants (not including vines), five herbaceous vines, ten shrubby vines, thirteen other shrubs and twenty-one trees. These are em-

braced in thirty-nine families, sixty-five genera, and seventy-two species.

DRAWINGS.

In general, camera-lucida drawings have been made to show the pits in the phloëm when found, to show sieve tubes and some of the adjacent tissues from three points of view. A Bausch and Lomb 1/12 objective was used with but few exceptions, and for measuring a Bausch and Lomb micrometer eyepiece—divisions 1/10 mm. In all about 175 drawings have been prepared for use in evidence.

FINDINGS.

PROBLEM I.—What special devices occur for the lateral transfer of food materials in the phloëm?

After considerable search I have found pits in the lateral walls of the phloëm of fourteen plants, as shown, for example, in figures 1 and 2. In figure 1 they are evidently between the medullary ray and the phloëm; in figure 2, between the sieve tubes and the adjoining cells.

Frank[1] seems to imply that there are no pits between the parenchyma cells of the phloëm. Figure 1 shows some as they appeared between the parenchyma and the parenchyma, and between the parenchyma and medullary-ray cells of the stem of *Populus alba*. He also states that the sieve tubes are the widest phloëm elements.[2] This is hardly true in quite a number of instances, as in *Amorpha fruticosa* (fig. 6), where the parenchyma is the wider. Quoting from Briosi,[3] he states that the slime bodies of the sieve tubes sometimes contain starch granules. Some are shown in figure 7 in *Populus alba*. They were noted also in *Rhus toxicodendron*. Frank states also[4] that the lateral walls of the sieve tubes are never strengthened. Figures 4 and 5 show thickenings on the lateral walls of the sieve tubes in the roots of *Populus deltoides*. It would seem that these are for strengthening the wall. They occur also in the end plates of the sieve tubes of the same plant (figs. 8 and 9) and in *Populus alba*.

Strasburger[5] finds pits between the phloëm parenchyma and the medullary rays. Figures 1, 2 and 3 show such. He also states[6] that the cortical rays are specially adapted by means

1. Frank, A. B.: Lehrbuch der Botanik, 1892, vol. I, p. 184.
2. Loc. cit., p. 183.
3. Loc. cit., p. 183.
4. Loc. cit., p. 183.
5. Strasburger, Ed., Textbook of Botany, 1897, p. 135. (Trans. by Porter.)
6. Loc. cit., p. 135.

of these pits and their contact with the companion cells for taking up and transferring the food materials laterally, especially to the cambium. Figure 6 shows a very common arrangement of the medullary rays which bears out the rest of his statement. It may be added to by saying that the medullary rays are often close to each other tangentially, and the rays and ray-like cells of the pericycle often sweep around the narrow portions of the phloëm, as seen in figure 6 of *Amorpha fruticosa,* as though for the special purpose stated above, and in a way especially fitting them for that function. Some recent research[7] has further verified Strasburger's statements in certain plants.[8]

One thing to be noted in botanical literature is that work on sieve tubes and sieve plates is usually done with plants from the Vitaceæ, Cucurbitaceæ, Tiliaceæ, and a few others, where, as will be seen by reference to table I, the walls of the phloëm are unusually thick. Presumably this is because here the things to be seen are more pronounced, and hence more easily found and studied. Table II shows comparative data collected from the plants having pits in the lateral walls of the phloëm as observed in this work and from those in which such pits were not observed. In *Equisetum* pits are general in the phloëm elements and in the rest of the cortical tissues. In others this is not true. In the tables mentioned it will be seen that pits are present in those plants having thicker walls than those in which pits were not observed, and, as a rule, the sections were from actively functioning tissue. It is seen that the phloëm walls are as thin in some cases as 0.25 micron, and in many cases 0.35 micron. In fact, in the phloëm in many instances there was but little evidence of appreciable addition in thickness to the original vertical wall formed by the cambium or procambium. As a result of this, in drawing with the high magnification of 1200 diameters, it was not feasible to use a double line for representing the thickness of the walls, and the attempt to do so was soon abandoned and choice made of the measurement and tabulation method as shown by the tables. It is quite plain that such thin walls could neither have nor require pits. In the xylem I found pits invariably

7. Hill, A. W., Histology of the Sieve Tubes of Angiosperms. Annals of Botany, vol. 22, No. 86, pp. 246-290.

8. Sykes, M. G., Anatomy and Histology of *Macrocystis pyrifera* and *Laminaria saccharina*. Annals of Botany, vol. 22, No. 86, pp. 291-326.

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present, but with the cell walls always much thicker. Even here there are no actual perforations.

Plants often adopt the device of obliquely placed end plates, possibly for the purpose of furnishing greater surface for the pits. This is noticeably true in many instances, especially in the Salicaceæ. As a result it seems necessary to strengthen these walls, and cross banding with thickenings in the walls are seen in figures 2, 8 and 9. The best illustrations (figs. 8 and 9) are from a root of *Populus deltoides*, taken about eight feet below the surface of the ground. Here there is a much increased sieve-plate surface, with strengthening bands at regular intervals, as seen from two directions.

PROBLEM II.—Are sieve tubes always present in the phloëm?

As to this problem, my data, many of which were obtained only after long search, are quite positive. Plants differ greatly in arrangement, location, number, size, staining qualities, etc., of their sieve tubes in the various specimens. However, one can be reasonably sure of their presence by noting the phloëm in cross section. The companion cells and the sieve tubes adjoining form units in outline, which, together with the protoplast of the companion cell and the slime body of the sieve tube, assist in the discovery (fig. 6). Sieve plates are not so easily found, unless it may be in those plants where sieve tubes are numerous, or where one happens to get a section through an unusually favorable place. For still better evidence the slime body is good, but the perforated sieve plate is best. I was usually not satisfied until all of these requirements were met, and the drawings were then made.

Perforations were not found in the end plates in *Pinus laricio*, *Sagittaria*, and *Asparagus*. They were quite numerous, although very small, in *Opuntia*. In *Myriophyllum*, a hydrophyte, they were evident, as in *Cuscuta*, a parasite. In this last were found cells of large dimensions, apparently serving especially as conducting cells. One was 0.1 mm. in tangential diameter by 1.62 mm. in axial length. We could not tell how much longer, because of the limits of the section. Sieve tubes are also present in *Tillandsia*, an epiphite. Here there is a cylinder of sclerenchyma inclosing the vascular bundles, and probably permitting of but little lateral transfer of foods.

Data concerning the sieve tubes are contained in tables I-IV.

It will be seen that the walls are commonly quite thin—those between them and the companion cells being thinnest. Thickness of their walls ranges from 0.25 micron to 4.17 microns.

PROBLEM III.—The facts observed concerning the third part of the problem are tabulated in table III. The tendency is shown to be toward a reduction of the diameter of the vessels in the fruitstalk and petioles, with an increase in thickness of the walls.

## RESUME.

*First.*—There are special devices for the better lateral transfer of foods present in the phloëm and cortex of the plants studied. These are (*a*) pitted walls; (*b*) the arrangement of the phloëm in narrow wedges with pericycle cells sweeping around these and connecting with the medullary rays, and (*c*) radially elongated medullary-ray cells adapted readily to conduct the food as stated. It is probable that in many plants the extreme thinness and large area of the phloëm walls permits a considerable lateral movement of materials without resort to pits, and that no pits are to be found in some (perhaps many) cases.

*Second.*—Sieve tubes with perforated sieve plates were demonstrated in all but three of the plants examined, and here I was satisfied of their presence. They often increase the area of their sieve plates by placing them obliquely, and these may require special thickenings to support them. The number of the sieve tubes in various species varies considerably. They are present in some plants when probably almost functionless.

*Third.*—Relatively, the phloëm and xylem do not vary greatly in amount in the various parts of the plants, such as the stems, petioles, etc., but the main differences in this respect are in the other tissues.

TABLE I. Thickness of cell walls in stems (measurements in microns).

| | Between adjoining sieve tubes | Between sieve tubes and companion cells | Between sieve tubes and medullary rays | Between tracheal tissues and xyl. parenchyma | Between tracheal tissues and medullary rays |
|---|---|---|---|---|---|
| Pinus laricio Bort | 0.65 | ..... | 0.65 | 2.58 | 1.60 |
| Saggittaria latifolia Willd | 0.35 | 0.32 | ..... | 1.50 | ..... |
| Zea mays L | 0.50 | 0.40 | ..... | 1.65 | ..... |
| Scirpus validus L | 0.30 | 0.25 | ..... | 1.50 | ..... |
| Tillandsia usneoides L | 0.30 | ..... | ..... | 1.30 | ..... |
| Smilax rotundifolia L | 1.00 | 0.60 | ..... | 1.65 | ..... |
| Yucca glauca Nutt. | 0.58 | 0.40 | ..... | 1.78 | ..... |
| Asparagus officinalis L | 0.35 | 0.30 | ..... | 2.79 | ..... |
| Salix alba, var. vitellina (L.) Koch | 0.40 | 0.35 | 0.40 | 1.85 | 1.28 |
| Juglans nigra L | 0.35 | 0.30 | 0.35 | 2.73 | 1.65 |
| Populus alba L | 1.08 | 0.53 | 1.25 | 2.73 | 1.65 |
| Populus deltoides Marsh | 0.50 | 0.35 | 0.50 | 2.80 | 1.85 |
| Ulmus Mx fulva | 0.35 | 0.30 | 0.35 | 3.53 | 2.61 |
| Ulmus americana L | 0.40 | 0.35 | 0.35 | 3.83 | 1.67 |
| Celtis occidentalis L | 0.35 | 0.25 | 0.40 | 2.31 | 1.56 |
| Cannabis sativa L | 0.35 | 0.25 | 0.35 | 2.60 | 1.72 |
| Humulus lupulus L | 0.30 | 0.30 | ..... | 3.86 | ..... |
| Morus rubra L | 0.35 | 0.30 | 0.35 | 2.75 | 1.60 |
| Asimina triloba Dunal | 0.40 | 0.35 | 0.55 | 3.08 | ..... |
| Clematis pitcheri T. & G | 1.28 | 0.92 | ..... | 3.72 | 3.50 |
| Menispermum canadense L | 0.45 | 0.40 | ..... | 2.48 | ..... |
| Deutzia fortunei Hort | 0.42 | 0.40 | 0.35 | 3.72 | 2.78 |
| Spiræa japonica L.? | 0.35 | 0.25 | 0.25 | 1.58 | ..... |
| Pyrus malus L | 0.50 | 0.40 | 0.55 | 3.11 | 1.72 |
| Rubus occidentalis L | 0.45 | 0.45 | 0.35 | 2.19 | 1.75 |
| Rubus cuneifolius Pursh | 1.65 | 1.71 | 3.30 | 3.65 | 1.85 |
| Prunus americana Marshall | 0.60 | 0.40 | 0.55 | 2.43 | 1.92 |
| Gymnocladus dioica (L.) Koch | 0.40 | 0.30 | 0.45 | 3.94 | 3.16 |
| Gleditsia triacanthos L | 0.65 | 0.30 | 0.58 | 2.94 | 2.46 |
| Melilotus alba Desr | 0.40 | 0.25 | 0.40 | 3.93 | 1.85 |
| Amorpha fruticosa L | 0.45 | 0.35 | 0.40 | 2.80 | 1.65 |
| Desmodium canescens (L.) DC | 0.40 | 0.33 | 0.40 | 2.70 | 2.08 |
| Zanthoxylum americanum Mill | 0.55 | 0.35 | 0.50 | 3.37 | 3.25 |
| Ailanthus glandulosa Desf | 0.50 | 0.35 | 0.45 | 4.48 | 3.61 |
| Rhus glabra L | 0.75 | 0.55 | 0.75 | 2.64 | 2.20 |
| Rhus toxicodendron L | 0.40 | 0.35 | 0.50 | 1.85 | 1.35 |
| Rhus cotinus Nutt | 0.55 | 0.55 | 0.90 | 2.35 | 1.50 |
| Celastrus scandens L | 0.50 | 0.38 | 0.50 | 3.08 | 1.85 |
| Acer saccharinum L | 0.68 | 0.55 | 1.00 | 2.35 | 2.00 |
| Acer negundo L | 1.00 | 0.45 | 0.85 | 2.60 | 1.87 |
| Rhamnus lanceolata Pursh | 0.50 | 0.35 | 0.70 | 2.50 | 1.80 |
| Psedera quinquefolia (L.) Greene | 0.70 | 0.50 | 0.50 | 2.20 | 1.85 |
| Vitis æstivalis Mx | 2.33 | 1.72 | 4.17 | 3.83 | 1.77 |
| Tilia americana L | 0.55 | 0.50 | 1.00 | 2.48 | ..... |
| Abutilon theophrasti Medic | 0.65 | 0.45 | 0.80 | 3.25 | ..... |
| Opuntia rafinesquii Engelm | 0.50 | 0.38 | ..... | 1.66 | ..... |
| Myriophyllum heterophyllum Mx | 0.50 | 0.30 | ..... | 3.10 | ..... |
| Cornus asperifolia Mx | 0.45 | 0.25 | 0.40 | 3.50 | 2.08 |
| Fraxinus viridis Mx.? | 1.15 | 0.75 | 1.30 | 4.47 | 2.27 |
| Syringa vulgaris L | 0.60 | 0.40 | 0.80 | 2.85 | 2.02 |
| Cuscuta glomerata Choisy | 0.42 | 0.35 | ..... | 3.40 | ..... |
| Lycium halimifolium Mill | 0.60 | 0.35 | ..... | 3.80 | ..... |
| Tecoma radicans Juss | 0.55 | 0.40 | 0.45 | 3.02 | 2.13 |
| Catalpa speciosa Warder | 0.45 | 0.25 | 0.30 | 2.46 | 2.15 |
| Sambucus canadensis L | 0.50 | 0.30 | 0.55 | 5.56 | 2.30 |
| Triosteum perfoliatum L | 0.60 | 0.40 | 0.50 | 4.44 | ..... |
| Symphoricarpos orbiculatus Moench | 0.60 | 0.40 | 0.50 | 2.78 | 1.92 |
| Brauneria pallida (Nutt) Britton | 0.65 | 0.35 | ..... | 2.68 | ..... |
| Gaillardia grandiflora | 0.50 | 0.45 | ..... | 3.25 | ..... |
| Minimum thickness of wall | 0.300 | 0.250 | 0.250 | 1.300 | 1.280 |
| Maximum thickness of wall | 2.330 | 1.720 | 4.170 | 5.560 | 3.610 |
| Average thickness | 0.598 | 0.430 | 0.715 | 2.866 | 2.095 |

TABLE II.

| | Thickness in microns of walls between— | | | | |
|---|---|---|---|---|---|
| | S. t. and s. t. | S. t. and comp. cells. | S. t. and m. ray. | Tracheal tissues and xyl. par. | Tracheal tissues and m. ray. |
| Pinus laricio Bort | 0.65 | ..... | 0.65 | 2.58 | 1.60 |
| Yucca glauca Nutt | 0.58 | 0.40 | ..... | 1.78 | ..... |
| Salix alba, var. vitellina (L.) Koch | 0.40 | 0.35 | 0.40 | 1.85 | 1.28 |
| Populus alba L | 1.08 | 0.53 | 1.25 | 2.73 | 1.65 |
| Populus deltoides Marsh. (stem) | 0.50 | 0.35 | 0.50 | 2.80 | 1.85 |
| Populus deltoides Marsh. (root) | 1.39 | 1.00 | 1.22 | 4.88 | 3.24 |
| Menispermum canadense L | 0.45 | 0.40 | ..... | 2.48 | ..... |
| Rubus occidentalis L | 0.45 | 0.45 | 0.35 | 2.19 | 1.75 |
| Gymnocladus dioica (L.) Koch | 0.40 | 0.30 | 0.45 | 3.94 | 3.16 |
| Celastrus scandens L | 0.50 | 0.38 | 0.50 | 3.08 | 1.85 |
| Psedera quinquefolia (L.) Greene | 0.70 | 0.50 | 0.50 | 2.20 | 1.85 |
| Vitis æstivalis Mx | 2.33 | 1.72 | 4.17? | 3.83 | 1.77 |
| Abutilon theophrasti Medic | 0.65 | 0.45 | 0.80 | 3.25 | ..... |
| Symphoricarpos orbiculatus Moench | 0.60 | 0.40 | 0.50 | 2.78 | 1.92 |
| Average for the above plants with pitted walls | 0.763 | 0.556 | 0.941 | 2.884 | 1.993 |
| Average from plants where pits were not observed | 0.549 | 0.394 | 0.633 | 2.922 | 2.133 |
| Difference (+) or (−) | +0.214 | +0.162 | +0.308 | −0.038 | −0.140 |

TABLE III. COMPARISON OF WALL THICKNESS IN STEMS, PETIOLES, AND FRUITSTALKS.
(Measurements in microns.)

| | Walls between s. t. and s. t. | | | Walls between s. t. and comp. cell. | | | Walls between s. t. and m. rays. | | | Diameter of sieve tubes. | | | Walls between tr. and xyl. parench. | | | Walls between tr. and m. rays. | | | Diameter of tracheals. | | | Length of sieve tubes. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stems | Petioles | Fruitstalks | Stems | Petioles | Fruitstalks | Stems | Petioles | Fruitstalks | Stems | Petioles | Fruitstalks | Stems | Petioles | Fruitstalks | Stems | Petioles | Fruitstalks | Stems | Petioles | Fruitstalks | Stems | Petioles | Fruitstalks |
| Vitis æstivalis Mx. | 2.33 | 2.37 | ..... | 1.72 | 2.33 | ..... | 4.17? | 2.33 | ..... | 20.83 | 14.25 | ..... | 3.83 | 3.09 | ..... | 1.77 | 2.92 | ..... | 72.90 | 36.40 | ..... | ..... | ..... | ..... |
| Rubus cuneifolius Pursh. | 1.65? | 1.80 | ..... | 1.71? | 1.55? | ..... | 3.30? | 1.50 | ..... | 13.03 | 8.45 | ..... | 3.65 | 4.02 | ..... | 1.85 | 2.24 | ..... | 41.47 | 28.35 | ..... | ..... | ..... | ..... |
| Cannabis sativa L. | 0.35 | 0.35 | ..... | 0.25 | 0.30 | ..... | 0.35 | 0.35 | ..... | 18.38 | 19.89 | ..... | 2.60 | 3.42 | ..... | 1.72 | 3.42 | ..... | 33.96 | 27.70 | ..... | ..... | ..... | ..... |
| Rhus glabra L. | 0.75 | ..... | 0.50 | 0.55 | ..... | 0.50 | 0.75 | ..... | 0.60 | 12.08 | ..... | 7.83 | 2.64 | ..... | 2.55 | 2.20 | ..... | 1.65 | 32.40 | ..... | 13.75 | ..... | ..... | ..... |
| Desmodium canescens DC. | 0.40 | ..... | 0.35 | 0.33 | ..... | 0.35 | 0.40 | ..... | 0.35 | 6.33 | ..... | 4.92 | 2.70 | ..... | 2.00 | 2.08 | ..... | ..... | 17.43 | ..... | 9.95 | ..... | ..... | ..... |
| Verbascum thapsus L. | 0.50 | ..... | 0.50 | 0.45 | ..... | 0.30 | 0.45 | ..... | 0.45 | 12.08 | ..... | 10.96 | 3.27 | ..... | 3.10 | 1.83 | ..... | 2.25 | 33.78 | ..... | 23.81 | 230.85 | ..... | ..... |
| Rhamnus lanceolata Pursh. | 0.50 | ..... | 0.50 | 0.35 | ..... | 0.40? | 0.70 | 1.70 | 0.75 | 13.16 | 11.53 | 5.08 | 2.50 | 4.00 | 3.50 | 1.80 | 3.33 | 2.16 | 23.76 | 15.95 | 15.75 | 97.6 | ..... | ..... |

TABLE IV. *Resume.*
(Measurements in microns.)

| | Walls between sieve tubes and sieve tubes. | Walls between sieve tubes and comp. cella. | Walls between sieve tubes and med. rays. | Diameter of sieve tubes. | Walls between tracheals and xyl. parench. | Walls between tracheals and med. rays. | Diameter of tracheals. | Length of sieve tubes. |
|---|---|---|---|---|---|---|---|---|
| Stems, only. | $0.598^{61}$ | $0.430^{59}$ | $0.715^{48}$ | $12.193^{9}$ | $2.866^{62}$ | 2.095 | $33.633^{13}$ | $183.608^{4}$ |
| Petioles, " | $1.317^{4}$ | $1.093^{3}$ | $1.470^{4}$ | $13.166^{8}$ | $3.526^{5}$ | $2.997^{3}$ | $30.612^{5}$ | ..... |
| Fruitstalks, only..... | $0.504^{11}$ | $0.364^{7}$ | $0.528^{7}$ | $8.302^{10}$ | $2.884^{11}$ | $2.229^{7}$ | $15.830^{10}$ | 182.180 |
| Roots, only. | $1.390^{1}$ | 1.000 | 1.220 | 41.640 | 4.880 | 3.240 | 206.55 | ..... |
| Minimum.... | 0.300 | 0.250 | 0.250 | 3.500 | 1.300 | 1.280 | 9.950 | 97.600 |
| Maximum.. | 2.330 | 1.720 | 4.170(?) | 41.640 | 5.560 | 3.610 | 206.55 | 256.780 |
| Average.... | 0.622 | 0.471 | 0.746 | 12.009 | 2.936 | 2.166 | 32.845 | 183.608 |